Phi-features reloaded: An ERP study on person and number agreement processing☆

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Abstract

Linguistic analysis claims that verb agreement is composed of distinct phi-features such as person and number. But are these different phi-features processed distinctly or similarly? In a sentence grammaticality task, we explored the electrophysiological responses of Basque speakers when processing subject-verb person and number phi-feature agreement violations. We generated grammatical structures (grammatical control) and ungrammatical structures in which the verb disagreed with the subject in person (person violation) in number (number violation) or in both person and number features (person+number violation). Behavioural data revealed that, overall, participants were faster and more accurate detecting person and person+number violations than violations involving only number. ERP responses revealed a N400-P600 pattern for all violation types. Importantly, person and person+number violations elicited larger P600 effects than number violations. These findings reveal different costs related to the processing of person and number phi-feature agreement and indicate that these features are distinct components of agreement computation.

Keywords: subject-verb agreement, phi-features, person, number, ERPs

1. Introduction

Agreement is a pervasive phenomenon of human language. The most frequent instance of agreement is that between a subject and a verb, where certain properties of the subject determine the form of the verb. Regarding the information transmitted, agreement is redundant, because the verb copies information that is already present in the subject. Subject-verb agreement (hereafter subject agreement) is illustrated in (1) with examples

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from Basque[1]:

1. a. Zu-k emakume-a ikusi d-u-zu[2]
   You-S woman-the seen $_{3SG}$have$_{S.2SG}$
   'You saw the woman'

   b. Ni-k emakume-a ikusi d-u-t
   I-S woman-the seen $_{3SG}$have$_{S.1SG}$
   'I saw the woman'

This linguistic dependency requires speakers to check that the subject and the verb of the sentence have the correct morphological features. In the examples above, when the subject is the addressee "you" (1a) the verb must carry the corresponding agreement marker *-zu*, and when the subject is the speaker "I" (1b) the verb must carry the corresponding agreement marker *-t*. Agreement is an asymmetric dependency, consisting of a trigger (also known as controller) and a target. It involves repeating bits of grammatical information copied from the trigger to the target (Corbett, 2006). In (1) above, the subject is the trigger, carrying information about number and person, and the verb is the target, displaying person and number morphology that co-varies systematically depending on the properties of the subject (Steele, 1978).

As discussed by Baker (2008), verbs are the prototypical and most prolific targets of agreement. Although there are many languages where adjectives and nouns can also enter into systematic co-variance with controllers, only verbs agree in person (Stassen, 1997). Due to this and other systematic differences between verbs on the one hand and adjectives/nouns/pronouns on the other, it is customary to refer to co-variance in the nominal domain as concord, restricting the term agreement for the co-variance shown by verbs. Another difference between concord and agreement is that agreement is not restricted to a single controller, that is, verb agreement is not limited to subjects cross-linguistically: in Basque, for instance, the verb must agree not only with the subject but also with the object and dative arguments of the sentence, and may agree with the person addressed in the conversation even if it is not an argument of the sentence (De Rijk, 2008). Psycholinguistic studies on agreement errors also reveal that agreement and concord show qualitatively different profiles: while agreement is reliably susceptible to intrusion from structurally illicit distractors, reflexive dependencies resist intrusion in identical environments, suggesting that agreement is not a uniform phenomenon (Dillon, Mishler, Sloggett & Phillips, 2013).

Despite the broad range of variation in agreement patterns across different languages, it is a well established typological generalization that subject agreement is the most frequent and basic agreement relation, and languages where agreement can be controlled by constituents other than subjects always show subject agreement as well. The features of the controller that enter into agreement are known as phi-features, and they are viewed as primitives of grammar (Rezac, 2011). Person is the most salient and prototypical phi-feature controlling agreement, followed by number and gender (Greenberg, 1963; Harley

[1] Note that in Basque the verb agrees also with the object. However, since object-verb agreement is not manipulated and is not relevant for the purpose of the current study, this phenomenon is not further discussed in the text.

[2] The following abbreviations have been used along the paper: S = subject; O = object; 1 = first person; 2 = second person; 3 = third person; SG = singular; PL = plural; MASC = masculine; FEM = feminine.

& Ritter, 2002). The repertoire of phi-features varies across languages but this variation is not random; Greenberg (1963) observed that other types of features are dependent on person and number: for instance, if the verb agrees with a nominal subject or nominal object in gender, it also agrees in number (Universal 32), and number related features such as trial and dual are dependent on having a singular/plural distinction (Universal 34). There is agreement in Linguistics regarding the saliency of person, followed by number, among the repertoire of phi-features, but there are competing views on the nature of these features and their combinations. Thus, for instance, Chomsky (1995, 2001) argues that phi-features are computed together as a cluster in syntactic derivation, whereas other authors (Boeckx, 2007; Nevins, 2011; Sigurdsson, 2009, among others) argue that person and number features undergo different derivational processes.

Although verb agreement is one of the most studied processes in psycholinguistics, there is scarce experimental evidence on how phi-features are processed. While many experiments have been carried out manipulating number feature in subject agreement (e.g. Hagoort, Brown & Groothusen, 1993, in Dutch; Osterhout & Mobley, 1995, in English; Münte, Matzke & Johannes, 1997, in German; Hinojosa, Martín-Loeches, Casado, Muñoz & Rubia, 2003, in Spanish; Paololahti, Leino, Jokela, Kopra & Paavilainen, 2005, in Finnish), few studies have focused on how person vs. number features are processed and whether similar or different processes underlie their computation; we will discuss them below.

One of the experimental techniques that have provided the most relevant evidence on the way agreement is processed is Event Related Potentials (ERPs). This issue has been mainly investigated by comparing grammatical and ungrammatical instances of verb agreement ('John *sings* a song' vs. 'John **sing* a song'). Three main ERP components have been reported in relation to agreement processing: Left Anterior Negativity (LAN), N400 and P600. Both LAN and N400 are negative wave deflections occurring between 300 and 500 milliseconds after the stimulus onset, while the P600 component, also labeled SPS (syntactic positive shift) is a centro-parietally distributed positive-going wave starting approximately 500 ms after the stimulus onset.

The LAN component is distributed over the left and anterior sites and has been interpreted as an electrophysiological response to morphosyntactic processes that occurs when processing ungrammatical information (Münte, Heinze & Mangun, 1993) or syntactically complex structures (Fiebach, Schlesewsky & Friederici, 2002; Rösler, Pechmann, Streb, Röder & Hennighausen, 1998). However, there has been a long debate about the nature of the LAN component, as it has not been consistently reported in many studies that manipulated morphosyntactic processing and the source of the variability between the presence/absence of LAN is still not clear (for a thorough review of the LAN see Molinaro, Barber & Carreiras, 2011; Tanner, 2014; Tanner & Van Hell, 2014). For instance, the LAN component has been also claimed to reflect working memory load (Martín-Loeches, Muñoz, Casado, Melcón & Fernández-Frías, 2005) and has been reported for semantically reversible sentences(Meltzer & Braun, 2013) or syntactic structures involving long-distance dependencies (e.g., wh-questions; Phillips, Kazanina & Abada, 2005).

On the other hand, unlike the LAN, the N400 component is a centro-parietal and slightly right-lateralized component that has been considered to respond to semantic, pragmatic or thematic violations (Hagoort, Hald, Bastiaansen & Petersson, 2004; Kutas & Hillyard, 1980) and to atypical thematic hierarchy (Bornkessel-Schlesewsky & Schlesewsky, 2009; Frisch & Schlesewsky, 2001). The N400 has been also found in non-linguistic contexts, such as meaningful environmental sounds in unexpected or incongruent contexts (e.g., animal sounds, telephone ringing) (e.g. Wu, Athanassiou, Dorjee, Roberts & Thierry, 2012), pictures, faces, movie clips or gestures (e.g. Grosvald, Gutiérrez, Hafer & Corina, 2012).

Finally, the P600 has been generally interpreted in terms of reanalysis or integration effects taking place when syntactically ungrammatical, ambiguous (Osterhout & Holcomb, 1992) or structurally complex information (Kaan, Harris, Gibson & Holcomb, 2000) is being parsed. Experimental evidence suggests that besides morphosyntactic processes, the P600 is also sensitive to non-syntactic factors such as semantic information (e.g., semantic reversal anomalies), processing strategies, and experimental tasks (Bornkessel-Schlesewsky, Kretzschmar, Tune, Wang, Genç, Philipp, Roehm & Schlesewsky, 2011) . Also, the P600 has been reported as response to non-linguistic tasks, such as rule violation in an arithmetic task (Núñez-Peña & Honrubia-Serrano, 2004) or incongruent chords in music (Sammler, Novembre, Koelsch & Keller, 2013).

1.1. Previous studies on person and number feature processing

To our knowledge only three studies so far have addressed the question and provided direct electrophysiological evidence on whether person and number features are processed similarly or differently. Nevins, Dillon, Malhotra & Phillips (2007) investigated how agreement violations of different combinations of phi-features are processed in Hindi. More precisely, in a grammaticality judgment task, they examined the electrophysiological responses elicited by agreement violations of gender and number, as well as agreement violations of one (gender or number) vs. two phi-features (e.g. gender+number or gender+person). ERP responses to all types of subject agreement violations elicited a P600 component (with no LAN/N400 components found). Interestingly, the P600 component elicited by the gender+person violations was larger than the ones elicited by all the other types of violations, while the gender+number violations did not differ from the responses to the individual gender or number violations. The authors conclude that the feature distance does not impact ERP responses since no amplitude differences were found among the gender, number and combined gender/number violations. On the other hand, larger P600 response to the violations involving the person feature are attributed to the greater saliency of this feature at multiple levels of representation.

Silva-Pereyra & Carreiras (2007) also used ERPs to explore how person and number agreement features are processed in Spanish. They visually presented native speakers with person, number and person+number violations, such as *tú juego* 'You$_{2SG}$ play$_{1SG}$ (...)', *nosotros juego* 'We play$_{1SG}$ (...)' and *vosotros juego* 'You$_{2PL}$ play$_{1SG}$ (...)'. All violations elicited a P600 component while only person+number violations yielded anterior negativity. Although all three ungrammatical conditions showed larger P600 amplitudes than the grammatical condition, no differences between person and number were reported, failing to provide evidence that phi-features are distinctly processed during agreement computation. The authors investigated two phases of the P600 component: the early one (500–700 ms), related with syntactic integration difficulty or diagnosis, and the late one (700–900 ms), reflecting reanalysis or repair processes (Friederici, Mecklinger, Spencer, Steinhauer & Donchin, 2001). The combination of two ungrammatical features triggered larger P600 amplitudes during its early phase only (500-700 ms) indicating additive processing effects of both person and number agreement. A similar P600 effect was found in all the three violations in the later stage of processing (700–900 ms). The authors concluded that the mechanisms of diagnosis, reanalysis or repair processes appear to be similar for both features.

More recently, Mancini, Molinaro, Rizzi & Carreiras (2011) investigated subject agreement computation by specifically targeting person and number features. Native speakers of Spanish read grammatical control sentences (i.e. *Los cocineros cocinaron (...)* 'The cooks$_{\text{3PL}}$ cooked$_{\text{3PL}}$') as well as sentences containing number (i.e. *El cocinero *cocinaron (...)* 'The cook$_{\text{SG}}$ cooked$_{\text{3PL}}$') and person violations (i.e. *El cocinero *cocinaste (...)* 'The cook$_{\text{3SG}}$ cooked$_{\text{2SG}}$'). Participants judged all three conditions with similar accuracy but they were significantly faster when judging number violations than when judging person violations and grammatical control sentences. ERP data for number agreement violations revealed a LAN component between 300 and 500 ms after the stimulus onset, and person agreement violations elicited an N400. The analysis of the 500–800 ms time window showed a P600 effect for both person and number violations; however, whereas number agreement violation effects were posteriorly distributed, person agreement violation effects were also significant over fronto-central sites. Finally, in the 800–1000 ms time window the analyses revealed larger positivity for person than for number violations, with the effects also spreading to fronto-central regions for person violations only. The authors interpreted the presence of LAN or N400 components as indicators of processing disruptions at different processing levels: the N400 component found in person violations would be a signature of a disruption at the semantic-discourse level, where interpretive relations among constituents are not preserved (i.e., when the subject is a speaker, 1$^{\text{st}}$ person; an addressee, 2$^{\text{nd}}$ person; or neither of the two, 3$^{\text{rd}}$ person); in contrast, the LAN components found in number violations would be a signature of a disruption at the morphosyntactic level. According to Mancini and colleagues, the increase of the P600 effect for person violations at the frontal regions suggests discourse-related integration difficulties, that is, the impossibility of integrating in the same discourse representations the incompatible speech participants (e.g., 3$^{\text{rd}}$ person vs. 2$^{\text{nd}}$ person addressee), as indicated by the anomalous subject-verb dependency. Additionally, the larger P600 amplitude for person than for number violations indicates higher repair cost for the former violation in comparison to the latter. Following this study, Molinaro *et al.* (2011) claim that agreement is sensitive both to the type of phi-features involved in the agreement relation and to the constituents that express the agreement dependency. According to the authors, this sensitivity is reflected by different ERP components: the LAN would reflect violation of expectancy elicited by the trigger, while the N400 would mirror additional, non-syntactic (discourse level) processes occurring during agreement computation.

Regarding Basque, the object of the present study, there is already some indirect evidence on how person vs. number features are processed. Zawiszewski & Friederici (2009) investigated subject and object-verb agreement (hereafter object agreement) processing. In a grammaticality judgment task, participants were visually presented with grammatical sentences and ungrammatical sentences containing either person or person+number agreement violations generated for both subject (*zu-k ni (...) na-u-zu / *na-u-te* 'You$_{\text{S.2SG}}$ me$_{\text{O 0.1SG}}$have$_{\text{S.2SG/*S.3PL}}$' "You have$_{\text{S.2SG/*S.3PL}}$ (...) me") and object (*zu-k ni (...) na-u-zu / *d-u-zu* 'You$_{\text{S.2SG}}$ me$_{\text{O 0.1SG/*O.3SG}}$have$_{\text{S.2SG}}$' "You have$_{\text{O.1SG/*O.3SG}}$ (...) me") agreement types. However, since the authors' main aim was to explore the differences in the processing of subject vs. object agreement, they did not make separate analyses for single vs. double feature violations. They observed similar ERP components towards both subject and object agreement violations, namely a N400 followed by a P600. The N400 was a novel finding not reported in the previous ERP literature for verb agreement violations (also found later by Mancini *et al.*, 2011, as mentioned above), while the P600 was highly expected as response to ungrammatical agreement. The authors interpreted the N400 component as indicating a failure to link previously presented arguments to the corresponding agreement morphology or to the difficulties engendered by having to keep track of more than one argument (subject and object) during agreement computation. The P600 was explained in terms of reanalysis and repair effects taking place during the late stage of processing.

Subsequently, Díaz, Sebastián-Gallés, Erdocia, Mueller & Laka (2011) further examined subject and object agreement in Basque, but only number agreement violations were tested in this study. In a grammaticality judgment task, participants were auditorily presented with grammatical and ungrammatical sentences containing subject (*arreb-ek egunkaria ekarri d-u-te / *d-u* 'The sisters$_{S}$ a newspaper$_{O}$ brought $_{O}$have$_{S.3PL/*S.3SG}$' "The sisters brought a newspaper") and object number agreement violations (*arreb-ek egunkariak ekarri d-it-u-z-te / *d-u-te* 'sisters$_{S}$ newspapers$_{O}$ brought $_{O.3PL/*O.3SG}$have$_{S}$' "The sisters brought newspapers"). In this occasion, different ERP patterns were reported for both types of number agreement violations: for subject violations only a P600 component was found, while for object violations the P600 was preceded by a posterior negativity between 200 and 300 ms after verb onset. Díaz *et al.* (2011) interpreted this negativity as an instance of a N200 component, related with the violation of participants' phonological expectancy about the upcoming morpheme (while in subject agreement violations hearing **du* matches the first syllable of the predicted dute, in object agreement violations listening the first syllable of **dute* does not match the first syllable of the predicted dituzte auxiliary verb). Importantly, they argued that the different ERP patterns reported for subject and object agreement violations in their study and that of Zawiszewski & Friederici (2009) could be attributed to the different phi-features manipulated (number vs. person) as well as to other potential factors (i.e. visual vs. auditory stimuli presentation, presence of single and double agreement violations).

Summing up, the experimental evidence shows that person, number and person+number violations elicit a P600 component (present in all the studies cited above). However, with regard to early ERP components, a different picture emerges: either no negativities are found for any of the feature violations (Nevins *et al.*, 2007), or similar anterior negativities are found for person, number and person+number violations (Silva-Pereyra & Carreiras, 2007) or LAN is found for number (Mancini *et al.*, 2011) and N400 for person violations (Mancini *et al.*, 2011; Zawiszewski & Friederici, 2009). Finally, when comparing single-feature vs. double-feature violations, larger amplitudes of the P600 have been found for double violations as compared to single ones in those cases where the person feature is involved (i.e. person+gender or person+number vs. single person and number violations Nevins *et al.*, 2007; Silva-Pereyra & Carreiras, 2007).

1.2. Caveats regarding previous studies

In light of the studies discussed above, it remains unclear whether person and number phi-features are processed similarly or whether different processes operate during their computation. Nevins *et al.* (2007) found no electrophysiological differences between number and gender agreement processing. However, limitations of the experimental design did not allow the authors to compare the electrophysiological responses towards person vs. number feature violations in isolation. Hence, no clear conclusions can be drawn on whether these features are processed differently or not. However, offline behavioural evidence (acceptability ratings, accuracy and response times) provided in their Experiment 2 showed that the conditions involving person feature violations were judged differently from the other violation conditions (lower acceptability ratings and faster and more accurate judgments). These behavioural differences suggest that person features might bear a different status in comparison to number or gender features, as suggested by some authors (Boeckx, 2007; Sigurdsson, 2009; Nevins, 2011).

The results of the ERP experiment carried out in Spanish by Silva-Pereyra & Carreiras (2007) did not clarify this issue either; the fact that the authors found no differences between person and number feature processing might be due to the experimental manipulations used in the study: the authors used the contrast between *yo* 'I' and *nosotros* 'we' as testing ground for number violations (*nosotros *juego* 'We play$_{\text{1SG}}$'). However, it has been widely argued in linguistics that the contrast between *I* and *we* involves more than a change in plurality. Specifically, whereas *I* necessarily involves the speaker, *we* is not a plurality of speakers, but a set containing more than one element where one is necessarily the speaker (Benveniste, 1966; Goddard, 1995; Ingram, 1978; Sørensen, 1958; Wierzbicka, 1972). In other words, while *I* is considered to be inherently singular, *we* is not a plurality of *I*-s (Jespersen, 1933; Lyons, 1968) and consequently the contrast between I and we would involve more than a mere number distinction form.

Subsequently, Mancini *et al.* (2011) found significant differences between person and number features. These authors used 3^{rd} person plural verb forms (*cocinaron* 'cooked$_{\text{3PL}}$') as a grammatical baseline to which the respective person and number violations were compared. However, in number violations the same plural verb forms as in the baseline (*cocinaron* 'cooked$_{\text{3PL}}$') were preceded by singular subjects (*el cocinero* 'the cook$_{\text{3SG}}$') while person violations were generated using the ungrammatical agreement between the singular verb (*cocinaste* 'cooked$_{\text{2SG}}$') with the singular subject (*el cocinero* 'the cook$_{\text{3SG}}$'). In other words, the comparison between the grammatical baseline and the number mismatch condition involved one manipulation (plural vs. singular subjects; same verb forms 'cooked$_{\text{3PL}}$'), while the comparison between the grammatical baseline and the person mismatch condition involved two manipulations (plural vs. singular subjects; different verb forms ('cooked$_{\text{3PL}}$' vs. 'cooked$_{\text{2SG}}$'). The fact that for person violations the critical verbs were preceded by a different context (singular vs. plural nouns) as well as that of having used 3^{rd} person as a testing ground might have influenced the final outcome. It has been widely argued in Linguistics that 3^{rd} person is not specified for person at all, that is, it contains no person feature (since Benveniste, 1966). Mancini *et al.* agree with this view that *"third person is specified for number, but not for person"* (p.67). Under this assumption, no true person violations can be generated using 3rd person agreement as a baseline and consequently the possibility that the results are due to the specific manipulations used in this study cannot be ruled out.

Finally, regarding the ERP studies in Basque, Díaz *et al.* (2011) reported ERP evidence concerning only number feature processing. However, the comparison between these results and those obtained by Zawiszewski & Friederici (2009), who only tested person and person+number violations, do not provide direct evidence that person and number phi-features are processed differently because neither study manipulated person and number features independently. Hence, these two studies do not allow direct comparisons between the reported results, and no firm conclusions can be drawn on the processes underlying person and number processing.

2. The present study

We acknowledge the difficulty of providing an experimental design that avoids all the main caveats mentioned above, as most languages tested so far did not allow controlling for all those factors. Previous research has provided very valuable information about the way different phi-features are processed during agreement computation. However, further pieces of evidence are needed in order to have a full picture of the puzzle. The present study aims at providing new evidence on how person and number agreement features are processed. We do it by investigating subject agreement in Basque, a head-final ergative language with very rich verbal morphology. These characteristics make it an appropriate testing ground to explore person and number feature processing in detail.

In order to avoid confounds of the sort reported for previous studies, we used a baseline condition that allowed us to generate subject-verb person violations where no 3rd person verb agreement forms were used (object agreement was not manipulated: 3rd person singular or plural objects were always used and they were kept constant across conditions; see Table 1). Hence, to test “pure” person violations, 2nd person verb forms (*d-u-zu* ‘$_{\text{O.3SG}}$have$_{\text{S.2SG}}$’ / *d-u-zue* ‘$_{\text{O.3SG}}$have$_{\text{S.2PL}}$’) were used as baseline and compared to 1st person forms (*d-u-t* ‘$_{\text{O.3SG}}$have$_{\text{S.1SG}}$’ / *d-u-gu* ‘$_{\text{O.3SG}}$have$_{\text{S.1PL}}$’). For testing number feature

Table 1: Sample of the materials used in the experiment.

CONDITION	**SENTENCE SAMPLE**					
(1) BASELINE	Zuk	mutila	bakarrik	utzi	**d-u-zu**	kalean.
	You-S	boy-O	alone	left	O$_{3SG}$-have-S$_{2SG}$	in-the-street
	‘You left the boy alone in the street’.					
(2) PERSON VIOLATION	Zuk	mutila	bakarrik	utzi	**d-u-t**	kalean.
	You-S	boy-O	alone	left	O$_{3SG}$-have-S$_{1SG}$	in-the-street
(3) NUMBER VIOLATION	Zuk	mutila	bakarrik	utzi	**d-u-zue**	kalean.
	You-S	boy-O	alone	left	O$_{3SG}$-have-S$_{2PL}$	in-the-street
(4) PER.+NUM. VIOLATION	Zuk	mutila	bakarrik	utzi	**d-u-gu**	kalean.
	You-S	boy-O	alone	left	O$_{3SG}$-have-S$_{1PL}$	in-the-street

violations, we also refrained from using 1st person verb forms as baseline, because, as mentioned above, the contrast between I and we has been argued to involve more than a change from singular to plural, given that I is necessarily the speaker but we is not a plurality of speakers (Jespersen, 1933; Lyons, 1968) and consequently no proper number violations can be generated. Hence, in our materials, the manipulation of subject-verb number feature involved strictly the contrast between the 2nd singular and plural persons (*-zu* vs. *-zue*), referring to one or more addressees.

In sum, unlike previous studies (Díaz *et al.*, 2011; Nevins *et al.*, 2007; Silva-Pereyra & Carreiras, 2007; Zawiszewski & Friederici, 2009), only 2nd person agreement verb forms were used here as a baseline to test how person and number violations are processed. Such a design allows us to directly test whether distinct mechanisms underlie person and number processing, and to further explore how the parser deals with single-feature vs. double-feature violations (similarly to Nevins *et al.*, 2007; Silva-Pereyra & Carreiras, 2007).

2.1. Hypotheses and predictions

Using the manipulations discussed above, three alternative hypotheses were considered. First, if different cognitive processes underlie person and number phi-feature computations, qualitatively different ERP responses to person and number violations could be expected: the LAN for number violations and the N400 for person violations (Mancini *et al.*, 2011; Molinaro *et al.*, 2011). However, when comparing single vs. double feature violations, no clear prediction can be made with respect to the expected electrophysiological pattern since the effects could overlap (e.g. LAN + N400 yielding a broad negativity) or even cancel one another out (broad negativity cancelling a P600). Secondly, if similar processes govern person and number feature computation but the cost related to the processing is different due to greater saliency of one feature over the other (Carminati, 2005; Greenberg, 1963; Harley & Ritter, 2002), then qualitatively similar but quantitatively different ERP signatures would be expected as response to person and number violations (e.g., larger ERP components for person than for number). According to these predictions, when comparing single vs. double violations we would expect violations involving the person feature (either person or person+number violations) to elicit larger effects in comparison to those elicited by the number feature only. Finally, if person and number are processed similarly and one is not cognitively more salient than the other (Silva-Pereyra & Carreiras, 2007), we expect the ERP responses towards both feature violations to be the same (but note that this interpretation is based on a null effect, and should be taken with caution). If this pattern emerges when comparing single vs. double violations we might expect either no differences or larger amplitudes for person+number violations as compared to only person and only number violations. The latter would indicate additive effects during feature processing, that is, that processing two ungrammatical phi-features is costlier than processing one ungrammatical phi-feature or that the saliency related to two ungrammatical features is greater than that present in one ungrammatical feature. Also, one might interpret this result as indicating that person and number features are processed independently during syntactic derivation (Boeckx, 2007; Sigurdsson, 2009; Nevins *et al.*, 2007; Nevins, 2011) rather than as an undifferentiated cluster (Chomsky, 1995, 2001).

3. Experiment

Participants. 24 neurologically healthy native speakers of Basque (undergraduates and graduates at the University of the Basque Country, UPV/EHU) participated in the experiment: (3 men, mean age 18.37 years, SD = 1.03). According to the Edinburgh Inventory for assessment of handedness (Oldfield, 1971) they were all right-handed. Data from 2 participants were excluded from the analyses because of excessive eye movements and other artifacts; consequently the results of 22 speakers were submitted to the statistical analyses. All participants were paid for their participation.

Materials. The experiment was carried out in standard Basque. 160 experimental sentences were created and each of them was presented in the following subject agreement experimental conditions (see examples 1 – 4 in Table 1): (1) grammatical subject agreement, (2) person violation; (3) number violation and (4) person+number violation. Half of the direct object nouns in the experimental conditions were singular and the other half were plural. Additional 240 grammatical filler sentences including 1st person and 3rd person subject agreement structures were added in order to make the material as diverse as possible. In sum, each participant read 400 sentences: 160 experimental sentences (40 per condition) and 240 fillers. All the lists were counterbalanced so that each participant read only one version of each sentence.

In (1) the verb 'have' agrees with the subject 'you' in person (2nd) and number (SG) features; in (2) the verb agrees with the subject in number (SG), but disagrees in person (1st); in (3) the verb agrees with the subject in person (2nd), but disagrees in number (PL) and finally in (4) the verb disagrees with the subject in both person (1st) and number (PL) features.

Procedure. Personal computers (Windows XP operating system) and Presentation® software (Version 16.0; www.neurobs.com) were used to present the stimuli. Before the real experiment started, participants were instructed about the EEG procedure and seated comfortably in a quiet room in front of a 17 inch monitor. All sentences were displayed in the middle of the screen word-by-word for 350 ms (ISI = 250 ms). A fixation cross (+) indicated the beginning of each trial. After each sentence participants saw the words *zuzen?* "correct?" or *oker?* "incorrect?" in the screen and participants were asked to judge the grammaticality of the previously displayed sentence by pressing one of two keyboard buttons (left Ctrl = correct; right Intro = incorrect). Half of participants used the left hand for correct responses and the other half the right hand. All the 400 sentences were distributed randomly over 4 blocks that lasted approximately 9 minutes each. Participants were given a short break between each block. Before the actual experiment participants ran a short training session of 5 trials. They were instructed to avoid blinking or moving when the sentences were being displayed and to make the grammaticality judgment as fast and accurately as possible. The whole experiment, including electrode-cap application and removal, lasted no longer than 1 h 30 min.

EEG recording. The electroencephalogram (EEG) was recorded from 32 active electrodes secured in an elastic cap (Acticap System, Brain Products, Gilching, Germany). Electrodes were placed on standard positions according to the extended Internationals 10-20 system in the following sites: Fp1/Fp2, Fz, F3/F4, F7/F8, FC5/FC6, FC1/FC2, T7/T8, C3/C4, Cz, CP5/CP6, CP1/CP2, P7/P8, P3/P4, Pz, PO9/PO10, O1/02, Oz. All recordings were referenced to FCz position and rereferenced off-line to the global average reference. Vertical and horizontal eye movements and blinks were monitored by means of two electrodes positioned beneath and to the right of the right eye. Electrode impedance was kept below 10 kΩ at all scalp and eye electrodes. The electrical signals were digitized on-line at a rate of 500 Hz by a BrainVision amplifier system and filtered off-line within a bandpass of 0.01-35 Hz. After the EEG data were recorded, the ocular correction procedure (Gratton, Coles & Donchin, 1983) as well as the artifact rejection procedure were applied (off-line). Trials with other artifacts were removed indicated by any voltage exceeding 150 µV and voltage steps between two sampling points exceeding 35 µV.

Data analysis. For the data analysis the following types of subject agreement violations were compared: Person agreement violations (*duzu* 'have$_{2SG}$' vs. **dut* 'have$_{1SG}$'; conditions 1 vs. 2 in Table 1, respectively); Number agreement violations (*duzu* 'have$_{2SG}$' vs. **duzue* 'have$_{2PL}$'; conditions 1 vs. 3); and Person+Number violations (*duzu* 'have$_{2SG}$' vs. **dugu* 'have$_{1PL}$'; conditions 1 vs. 4). For the ERP measures, segments were constructed from

200 ms before and 1000 after the onset of the critical words (the verb) in the sentences. The trials associated with each sentence type were averaged for each participant. The EEG 200 ms prior to the onset was also used as a baseline for all sentence type comparisons. After the baseline correction, epochs with artifacts were rejected, which resulted in the exclusion of 10.85% (SDE = 2.3) of the trials across conditions. Based on the literature and visual inspection of the data, 300-500 ms and 500-800 ms temporal windows were considered during statistical analysis for all conditions. After the stimuli were recorded and averaged, ANOVA analyses were carried out in nine regions of interest (ROI) that were computed out of 21 electrodes: lateral electrodes: left frontal (F7, F3), left central (FC5, C3), left parietal (CP5, P3), right frontal (F4, F8), right central (C4, FC6) and right parietal (P4, CP6); midline electrodes: frontal (Fp1, Fz, Fp2), central (FC1, Cz, FC2), parietal (CP1, Pz, CP2). Repeated-measures ANOVA analyses were performed over all experimental manipulations and trials (correctly and incorrectly judged trials) for each window of time using three within-subjects factors: grammaticality (4 levels: grammatical, person violation, number violation, person+number violation), hemisphere (2 levels: left and right) and region (3 levels: frontal, central and parietal). Midline (frontal, central and parietal) electrodes were analyzed independently. Whenever the sphericity of variance was violated, *Greenhouse-Geisser* correction was applied to all the data with greater than one degree of freedom in the numerator. Finally, further statistical comparisons were conducted (split by the grammaticality condition) whenever an interaction turned out to be statistically significant. Effects for the hemisphere or region factors are only reported when they interact with the experimental manipulation.

For the behavioural results, error rates and response latencies of all the trials were submitted to by-subject (F_1) and by-item (F_2) repeated measures ANOVA analyses with grammaticality condition (4 levels: grammatical, person violation, number violation, person+number violation) as a within-subjects factor. Subsequent by-subject (t_1) and by-item (t_2) paired t-tests were carried out whenever the effect was significant. In order to avoid Type I errors, Bonferroni correction was used and only the contrasts with the p values below 0.0083 (0.05 / 6 tests) were considered significant.

3.1. Behavioural results

Grammaticality judgment errors. Participants overall showed a high grammaticality judgment accuracy (mean accuracy of 94.1%, SDE= 1.97; see Table 2). The analysis of accuracy data revealed that there was a significant difference between the grammaticality conditions (F_1 (3, 63) = 15.42, $p < .001$, $\varepsilon_{\mathrm{GG}} = .444$; F_2 (3, 477) = 59.95, $p < .001$, $\varepsilon_{\mathrm{GG}} = .760$). Statistical pair-wise tests showed that in comparison to the grammatical baseline the participants committed more errors in the number condition (t_1 (21) = -3.56, $p = .006$, t_2 (159) = -7.11 , $p < .001$), and less errors in the person condition, although these differences were only significant in the analysis by items (t_1 (21) = 2.29, $p = .032$, t_2 (159) = 3.02, $p = .003$). No differences were found between baseline and person+number conditions (t_1 (21) = 2.26, $p = .034$; t_2 (159) =2.59, $p = .010$). Also, error rates were significantly lower in person and person+number conditions compared to the number condition (person vs. number: t_1 (21) = 5.09, $p < .001$; t_2 (159) =-10.32, $p < .001$; person+number vs. number: t_1 (21) = 4.47,$p < .001$; t_2 (159) = -10.65, $p < .001$). *Grammaticality judgment response latencies.* Similarly to the accuracy data, the results of the response time data showed differences between the four grammaticality conditions (F_1 (3, 63) = 11.26, $p < .001$, $\varepsilon_{\mathrm{GG}} = .549$; F_2 (3, 477) = 30.90, $p < .001$,

$\varepsilon_{GG} = .851$). Further paired comparisons revealed that, compared to the grammatical sentences, the participants needed significantly less time to make grammaticality judgments in the ungrammatical person (t_1 (21) = 4.31, $p < .001$; t_2 (159) = 7.8, $p < .001$) and person+number conditions (t_1 (21) = 4.11, $p < .001$; t_2 (159) =7.42, $p < .001$), while no differences were found when comparing the grammatical baseline to the ungrammatical number condition in the analysis by subjects (t_1 (21) = 1.77, $p = .09$; t_2 (159) =3.81, $p < .001$). Also, the participants needed more time to judge the grammaticality of sentences containing number violations than to judge the grammaticality of sentences containing person violations (t_1 (21) =-2.86, $p = .009$; t_2 (159) = -3.63, $p < .001$) or person+number violations (t_1 (21) = 3.17, p =.001; t_2 (159) = -5.33; $p < .001$).

Table 2: Mean reaction times and percentage of correct responses with their corresponding standard errors (SDE) per experimental condition.

	REACTION TIMES		**% OF CORRECT RESPONSES**	
	Mean	SDE	Mean	SDE
Grammatical baseline	687	62	95.1	1.1
Person violations	541	42	98.0	0.7
Number violations	611	45	85.7	3.1
Person+number violations	528	37	97.7	0.6

3.2. ERP results

The analyses carried out over the lateral electrodes within the 300–500 ms time window revealed a significant grammaticality × hemisphere × region interaction (F (6, 126) = 3.30, p = .015, ε_{GG} = .653). The comparison between all the four grammaticality conditions carried out over the midline electrodes yielded no statistically significant results. The analyses carried out over the lateral electrodes within the 500–800 ms time window showed significant grammaticality × hemisphere (F (3, 63) = 9.04, p = .001, ε_{GG} = .655) and grammaticality × region interactions (F (6, 126) = 6.66, p = .001, ε_{GG} = .414) while the analyses carried out over the midline electrodes revealed a significant grammaticality × region interaction (F (6, 126) = 11.49, $p < .001$, ε_{GG} = .468).

In order to better understand these interactions, on one hand we conducted follow-up analyses comparing each of the three main agreement violations separately against the control grammatical sentence and on the other hand, each violation type against the other two ungrammatical conditions.

3.3. Main grammaticality effects per condition

3.3.1. 300–500 ms time window

Person violations. Further analyses of the grammaticality × hemisphere × region interaction showed that person violations elicited a larger negativity than the grammatical baseline over the left posterior sites of the scalp (F (1, 21) = 4.82; p = .040) as well as marginally larger negativity over the right posterior region ((F (1, 21) = 3.34, p = .082).

Number violations. The analysis of the grammaticality × hemisphere × region interaction revealed that, in comparison to the grammatical agreement condition, number violations elicited a larger negativity over the left posterior (F (1, 21) = 27.84, p < .001) and the right posterior regions (F (1, 21) = 4.49, p = .046), which was accompanied by a larger positivity over the left anterior site (F (1, 21) = 7.42, p = .013).

Person+number violations. The follow-up analyses of the grammaticality × hemisphere × region interaction showed that the person+number violations elicited a marginally larger negativity than the grammatical baseline over the right posterior region (F (1, 21) = 3.42, p = .079).

3.3.2. 500-800 ms time window

Person violations. Subsequent analyses of the grammaticality × hemisphere interaction revealed that the person violations elicited a larger negativity than the grammatical baseline condition over the left hemisphere (F (1, 21) = 14.38, p = .001) and a marginally larger negativity over the right hemisphere (F (1, 21) = 3.57, p = .073). The analyses of the grammaticality × region interaction revealed that person violations elicited a larger negativity than grammatical stimuli over the frontal region accompanied by a larger positivity over posterior electrodes (frontal region: F (1, 21) = 9.98, p = .005; central region: F (1, 21) $<$ .001, p = .952; posterior region: F (1, 21) = 7.31, p = .013).

Further analyses of the grammaticality × region interaction carried out over the midline electrodes showed that person violations elicited a larger negativity over frontal and a larger positivity over central and posterior regions of the scalp as compared to the grammatical condition (frontal region: (F (1, 21) = 5.69, p = .027; central region: F (1, 21) = 5.33, p = .031; posterior region: F (1, 21) = 57.39, $p < .001$).

Number violations. The follow-up analyses of the grammaticality × hemisphere interaction revealed that, in comparison to the grammatical condition, number violations elicited a larger negativity over the left hemisphere (F (1, 21) = 10.28, p = .004) and a marginally larger positivity over the right hemisphere (F (1, 21) = 3.40, p = .079). The analyses of the grammaticality × region interaction revealed that number violations elicited a larger negativity than grammatical stimuli over the frontal region accompanied by a larger positivity over posterior electrodes (frontal region: F (1, 21) = 8.81, p = .008; central region: F (1, 21) = 0.24, p = .628; posterior region: F (1, 21) = 4.74, p = .041). The analyses of the grammaticality × region interaction carried out over the midline electrodes revealed that number violations elicited a larger positivity than grammatical stimuli over central and posterior regions (frontal region: F (1, 21) = 0.68, p = .419; central region: F (1, 21) = 5.27, p = .032; posterior region: F (1, 21) = 26.00, p $<$ .001).

Person+number violations. Further analyses of the grammaticality × hemisphere interaction revealed that person+number violations elicited a larger negativity than grammatical stimuli over the left hemisphere (F (1, 21) = 15.37, p = .001) accompanied by a larger positivity over the right hemisphere (F (1, 21) = 9.16, p = .006). The analyses of the grammaticality × region interaction conducted over the lateral electrodes revealed that, compared to the grammatical baseline, person+number violations elicited a larger positivity at the posterior region accompanied by a frontal negativity (frontal region: F (1, 21) = 15.43, p = .001; central region: F (1, 21) = 0.21, p = .654, posterior region: F (1, 21) = 22.03, $p < .001$). The analyses of the grammaticality × region interaction carried out over the midline electrodes revealed that person+number violations elicited a larger negativity than grammatical stimuli over frontal sites and a larger positivity over the central and posterior regions of the scalp (frontal region: F (1, 21) = 12.90, p = .002;

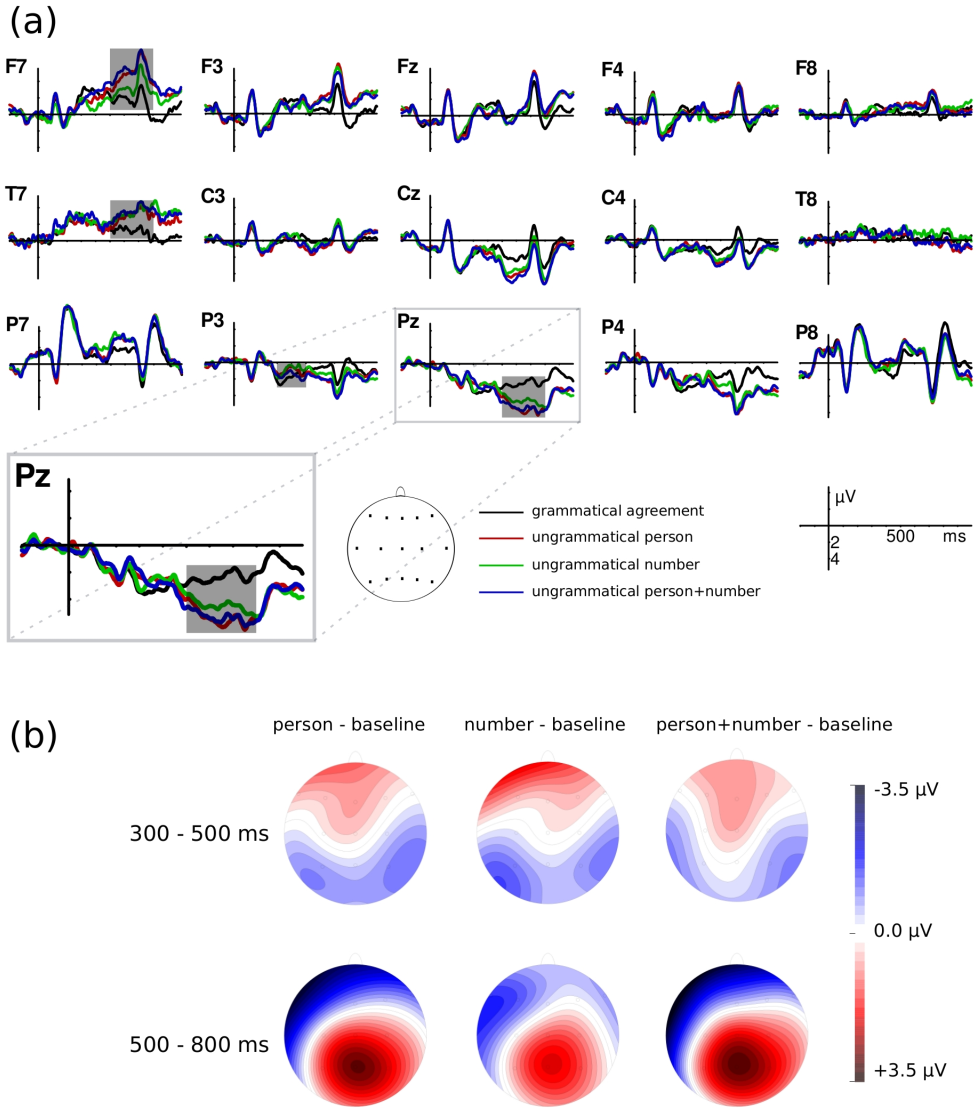

Figure 1: (a) Event-related potentials elicited at the critical word position in all conditions. The black line represents the grammatical baseline, the red line stands for the ungrammatical person feature violations, the green line represents number feature violations and the blue line represents person+number feature violations. Major significant differences between the grammaticality conditions are highlighted by the gray areas. (b) Topographical amplitude difference maps for the grammaticality effect in all conditions, calculated as the average difference amplitude between each ungrammatical condition and the grammatical baseline.

central region: $F\,(1,\,21) = 10.98$, $p = .003$; posterior region: $F\,(1,\,21) = 52.07$, $p <$ .001).

3.4. Comparing person and number phi-feature violations

300–500 ms time window. The analysis of the grammaticality × hemisphere × region interaction revealed no statistically significant effect.

500–800 ms time window. The analyses of the grammaticality × hemisphere as well as the grammaticality × region interactions conducted over the lateral electrodes yielded no statistically significant results. The analyses of the grammaticality × region carried out over the midline electrodes revealed that, compared to number violations, person violations elicited a larger negativity over the frontal regions, as well as a larger positivity over posterior sites of the scalp (frontal region: $F\,(1,\,21) = 6.80$, $p = .016$; central region: $F\,(1,\,21) = 0.80$, $p = .382$; posterior region: $F\,(1,\,21) = 5.92$, $p = .024$).

3.5. Comparing person and number single-features vs. person+number double-feature violations

300–500 ms time window. The follow-up analysis of the grammaticality × hemisphere × region interaction revealed no differences between person violations and person+number violations. In contrast, number violations showed a larger negativity than person+number violations over the left posterior site (F (1, 21) = 5.79, p = .025).

500–800 ms time window. The analysis of the grammaticality × hemisphere interaction showed no differences between person and person+number violations or between number and person+number violations. The subsequent analyses of the grammaticality × region interaction carried out over the lateral and midline electrodes yielded no significant effects between person violations and person+number violations. In contrast, the comparison between number violations and person+number violations conducted over the lateral electrodes showed a larger positivity for person+number violations than number violations over the posterior regions of the scalp (frontal region: $F\,(1,\,21) = 1.88$, $p = .185$; central region: $F\,(1,\,21) = 2.18$, $p = .155$; posterior region: $F\,(1,\,21) = 6.31$, $p = .02$). At the midline electrodes the same comparison revealed a larger negativity for person+number violations than number violations over frontal sites as well as a marginally larger positivity for person+number violations than number violations over the central region and a larger positivity over posterior sites (frontal region: $F\,(1,\,21) = 11.32$, $p = .003$; central region: $F\,(1,\,21) = 3.95$, $p = .06$; posterior region: $F\,(1,\,21) = 5.04$, $p = .036$).

3.6. Summary of the results

Behavioural results showed that person violations and person+number violations were judged with higher accuracy than number violations. The response times revealed a very similar pattern: participants were slower detecting the ungrammaticality of sentences containing number violations than those containing both person violations and person+number violations. These results suggest that person and person+number agreement violations are more salient and therefore easier and faster to detect than number agreement violations.

ERP data showed that in comparison to grammatical stimuli, overall all violation conditions elicited similar ERP components: a posterior negativity between 300 and 500 ms

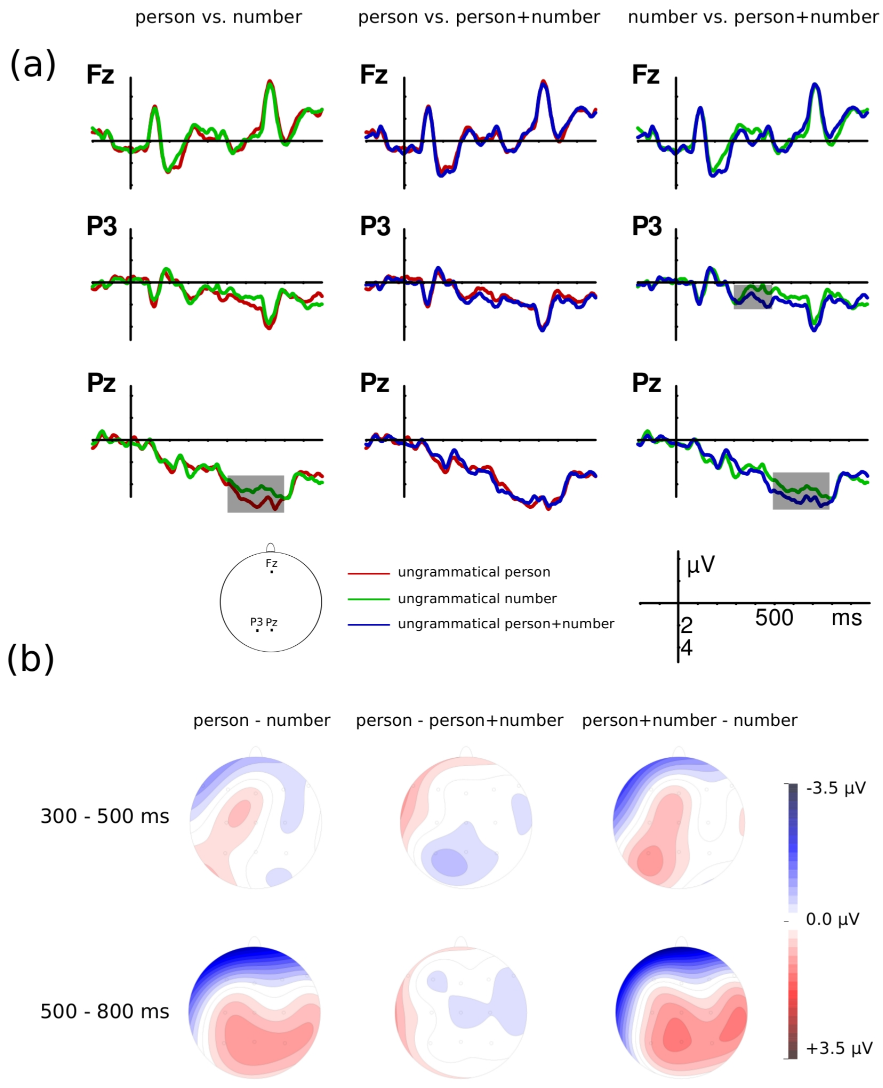

Figure 2: (a) Comparison of the effects elicited by the ungrammatical conditions at the critical word position at Fz, P3 and Pz electrodes. The red line stands for the ungrammatical person feature violations, the green line represents number feature violations and the blue line represents person+number feature violations. Major significant differences between the grammaticality conditions are highlighted by the gray areas. (b) Topographical amplitude difference maps calculated as the average difference amplitude between the ungrammatical conditions (person minus number, person minus person+number and person+number minus number).

after the stimulus onset (although only marginally significant for person+number violations). Although its distribution is not "classic" (centro-parietal) (Kutas & Hillyard, 1980) given its latency (300 ms) and posterior (rather than frontal) distribution we labeled it as a N400. The posterior negativity was followed by a positivity, which we interpreted as a classic P600 component. This posterior positivity was accompanied by a late negative component present over the lateral and frontal regions of the scalp. Importantly, the comparisons of the magnitude of these two main ERP components between the three different types of violations revealed the following patterns: (a) in the 300-500 ms time window, no differences were found between person and number violations or between person and person+number violations, while number violations elicited a larger negativity over left-posterior sites than person+number violations; and (b) in the 500-800 ms time window, no differences were found between person and person+number violations, whereas both person and person+number violations elicited a larger P600 than number violations over posterior sites accompanied by a larger negativity over frontocentral sites.

4. General discussion

The current study investigated whether person and number phi-features are distinctly processed during verb-agreement computation. To this purpose, we tested how native speakers of Basque dealt with ungrammatical sentences where subject agreement relations were violated in either person, number or both person+number features. Previous experiments carried out in Hindi, Basque and Spanish yielded contrasting results: some studies found no differences in processing person and number feature violations (Nevins *et al.*, 2007; Silva-Pereyra & Carreiras, 2007), while others reported distinct ERP signatures for each phi-feature violation, suggesting they are processed differently (Zawiszewski & Friederici, 2009; Díaz *et al.*, 2011; Mancini *et al.*, 2011).

Our results revealed qualitatively similar but quantitatively larger ERP signatures for person than for number violations. Concurrently, behavioural results revealed that participants made more errors and were slower when processing number violations as compared to person violations. All together, these findings lend support to the hypothesis that similar processes govern person and number agreement computation, but that the person phi-feature is cognitively more salient than the number phi-feature, as argued by Greenberg (1966), Harley & Ritter (2002), Carminati (2005) and Nevins *et al.* (2007), among others.

More specifically, in the case of the ERP results, both person and number violations elicited a N400, followed by a P600. A similar pattern was also observed during ungrammaticality detection of sentences containing person+number feature violations. The two conditions including person feature violations (person and person+number conditions) did not show any difference in their ERP patterns. However, the amplitude of the P600 was significantly larger in the conditions including person feature violations compared to the condition including number feature violations. Together with the results from the behavioural task where higher accuracy and shorter response times were found in person and person+number violation than in number violation conditions, the larger P600 for the former than for the latter conditions suggests that these violations are more salient and that Person has a special status among agreement features (see Nevins *et al.*, 2007, Experiment 2 for similar results and conclusions). In order to investigate whether there is a relationship between the amplitude of the P600 component and the behavioural performance of the participants, we computed a correlation analysis in which we included accuracy scores and the amplitude of the P600 component corresponding to each condition. The two-tailed correlation analyses showed no dependency between both factors, that is, the number of errors did not correlate with the changes of the P600 in any condition (Grammatical subject agreement: $r(22) = -.247$, $p = .268$; Person violations: $r(22) = .088$, $p = .697$; Number violations: $r(22) = -.047$, $p = .835$; Person+number violations: $r(22) = -.247$, $p = .267$). Additionally, in comparison to person+number violations, number violations elicited a larger negativity over the left-posterior region of the scalp. A deeper look at this effect revealed that although all violations elicited a larger negativity at this region as compared to the grammatical baseline, the magnitude of the effect in the 300-500 time window was largest in number violations (-0.97 μV) followed by person (-0.61 μV) and person+number violations (-0.32 μV). These gradual changes in the amplitude of the N400 (statistically reliable only for the comparison between number and person+number violations) might reflect difficulties during error identification (greater for number as compared to person and person+number violations). As suggested by an anonymous reviewer, the effect described as negativity could be also interpreted as an instance of the P300 component. The P300 effect can be modulated by many factors: i.e. expectancy, probability of the upcoming target, task difficulty, etc. (Picton, 1992; Osterhout, McKinnon, Bersick & Corey, 1996). Picton (1992) showed that the amplitude of the P300 varies depending on how difficult the discrimination task is, so that if the task of discriminating the target stimulus from the standard stimulus is difficult, the amplitude of the P300 tends to become smaller and its latency longer. If we interpret the grammatical condition as "standard" and the ungrammatical conditions as "targets", then our data are consistent with this view. In any case, both interpretations (N400 or P300) suggest that the changes in the amplitude of the N400 / P300 might reflect difficulties during error identification (greater for number as compared to person and person+number violations).

In contrast, the larger P600 amplitudes found in person and person+number violations as compared to the number violations reveal greater difficulties during the repair/revision phase for the former conditions as compared to the latter one.

Put together, our results reveal greater prominence of the person phi-feature as compared to number during the computation of person+number agreement violations, since the effects yielded by number violations were overridden by those elicited by person violations, at least at late stages of agreement processing.

4.1. Comparison of the current experiment with previous studies

Regarding the results from Spanish reported by Silva-Pereyra & Carreiras (2007), two major differences can be observed. First, in our study in Basque all violations led to a biphasic N400-P600 pattern. In contrast, in Spanish person and number violations only yielded a P600, while the biphasic anterior negativity followed by a P600 was only reported for person+number violations. These apparently contrasting findings may be due to differences between the experimental manipulations in these studies: while Silva-Pereyra & Carreiras (2007) used 1st person to test number violations, we used 2^{nd} person. The N400-P600 ERP patterns related to subject agreement violations in our study are the same as those previously obtained by Zawiszewski & Friederici (2009) related to subject and object agreement violations in the same language, Basque. Importantly, both studies used single person or double person+number violations when testing subject agreement. However, the ERP responses in the present experiment differ from those reported by Díaz et al. (2011). They found a P600 elicited by both subject and object agreement violations preceded by posterior negativity between 200 and 300 ms in object agreement violations, while the manipulations used in the current study led to a N400–P600 pattern. As suggested in the introductory section, besides the possible influence of the way the stimuli were presented (auditorily vs. visually), the differences at early stages of processing (between 300 and 500 ms) are likely due to the fact that Díaz et al. (2011) tested number feature violations only (3^{rd} person verb forms) while in our study we also tested the person feature (2^{nd} person verb forms).

Our results are consistent with those reported by Mancini et al. (2011) in finding differences between person and number phi-feature processing. However, the way in which these features differ diverges significantly in both studies. Unlike the present study, Mancini et al. (2011) found that participants were faster judging the grammaticality of sentences with number than person violations, but it did not find behavioural accuracy differences between the conditions. Also, in contrast to the N400–P600 pattern reported here for Basque, in Mancini et al. (2011), number violations in Spanish elicited a LAN followed by a P600 component and only person violations yielded N400–P600 effects. The amplitude of the P600 was similar in both number and person violations over the parietal sites, but larger for person than for number violations over the frontal sites, which, according to the authors, was due to discourse-related integration difficulties. In sum, the pattern reported by Mancini et al. (2011) suggests that person and number features processing are different operations, as indicated by the qualitatively different ERP components (LAN vs. N400).

The results of the current study do not support this claim, since person and number violations displayed a similar N400-P600 pattern. The different findings in both studies may be attributed to the differences between experimental materials used: 3^{rd} person agreement as a testing ground for person and number violations and critical words preceded by different contexts in Mancini et al. (2011) vs. 2^{nd} person agreement as a comparison point for all types of violations and critical words preceded by the same context in our study. Alternatively, it might reflect differences in processing strategies when dealing with Basque and Spanish verb agreement. More precisely, in Spanish the finite verb only agrees with the subject of the sentence, while in Basque it agrees with both the subject and the object of the sentence and consequently both arguments need to be taken into account when processing verb agreement structures. Even if we kept object agreement constant across the experiment (3^{rd} person singular or plural), it cannot be ruled out that when more than one constituent is involved in agreement processes the thematic dependencies of the arguments also play a role in agreement computation. This might be the reason why a N400 emerges in Basque independently of the type of feature involved. In this regard, partial evidence supporting this argument comes from the diverging patterns of results showed by studies investigating subject agreement that used animate vs. inanimate objects: note that both Zawiszewski & Friederici (2009) and the present study used animate objects while Díaz et al. (2011) used inanimate objects. In those cases in which both the subject and the object are animate, the likelihood of the object argument to be misinterpreted as a candidate for subjecthood due to its animacy feature may make agreement computation more demanding in comparison to the cases where the subject is animate and the object is inanimate. Consequently, since in order to identify and repair the error the parser must deal with the thematic dependencies of the arguments, a N400 is elicited.

Finally, in addition to the parietal positivity observed between 500–800 ms, we also found a negative component, mostly distributed over the left and frontal areas of the scalp.

Late frontal negativities have been previously described as related to working memory and task demands (Sabourin, Stowe & de Haan, 2006; Sabourin & Stowe, 2004). Sabourin & Stowe (2004) suggested that this type of negativity could be related to the effect of maintaining the ungrammaticality in memory until a delayed grammaticality decision is made at the end of the sentence. Our findings are compatible with this view: the negativity was larger for person and person+number violations in comparison to number violations, suggesting that memory-related processes involved during later stages of agreement computation are more demanding in the former conditions as compared to number violations.[3]

However, it could be argued that the differences observed between the number feature and other violations might be due to the visual saliency or length differences between the auxiliary forms of the various violation conditions.[4] For instance, the visual saliency and length differences between the grammatical baseline (*duzu* 'have$_{\text{2SG}}$') and the number feature violations (**duzue* 'have$_{\text{2PL}}$') seem smaller in comparison to those between the grammatical baseline and person (*duzu* vs. **dut* 'have$_{\text{1SG}}$') or person+number feature violations (*duzu* vs. **dugu* 'have$_{\text{1PL}}$'). Hence, it might be that part of the differences between the number vs. person and person+number violation conditions is due to to their visual saliency differences, and not to the greater prominence of the person phi-feature as compared to number phi-feature. This is a caveat that cannot be easily avoided, and it also affects other ERP studies that investigated subject-verb agreement relations.

For instance, (Nevins *et al.*, 2007, Experiment 1) found that, compared to the grammatical baseline, a larger P600 was found for the person+gender violation, while no modulation of the P600 was found when contrasting the grammatical baseline with the gender violation, the number violation, and the gender+number violation. In this case, although they interpret this finding as evidence of the special status of the person among the other features, they do not discard the possibility that the larger P600 may have been modulated by the greater orthographic/visual saliency of the Devanagari script (in which the stimuli were presented; see Nevins *et al.*, 2007) in the case of person+gender violations than in the other type of violations. However, in the study of Silva-Pereyra & Carreiras (2007), the comparisons in Spanish involved the contrasts *yo abro* ''I open$_{\text{1SG}}$' (grammatical) vs. *yo *abrimos* 'I open$_{\text{1PL}}$' (number violation) vs. *yo *abres* 'I open$_{\text{2SG}}$' (person violation) vs. *yo *abren* 'I open$_{\text{2PL}}$' (person+number violation). Although the differences between *abro* vs. **abrimos* may be considered more visually salient than those between *abro* vs. **abres* (e.g., the latter shares the same length and syllabic structure), the two comparisons yielded similar P600 components. This suggests that the role of visual saliency in this type of tasks might be rather limited. Finally, in a study that aimed to explore the impact of the phonological realization of visually presented morphosyntactic agreement in French, Frenck-Mestre, Osterhout, McLaughlin & Foucart (2008) compared the following subject agreement conditions: *je mange* ('I eat$_{\text{1SG}}$' (/ʒə mãʒə/; grammatical) vs. *je *mangez* 'I eat$_{\text{2PL}}$' (/ʒə mãʒe/; phonologically realized) vs.*je *manges* 'I eat$_{\text{2SG}}$' (/ʒə mãʒə/; phonologically silent). Despite the similar difference in visual saliency between the baseline con-

[3] As suggested by an anonymous reviewer, the negativity reported here emerges earlier than in the cited studies and therefore further research is needed in order to determine whether these negativities reflect the same process or not. Also, our data show that both the parietal positivity and the frontal negativity emerge in the same time window (500 – 800 ms) and consequently, the possibility of interpreting this effect as a phase-reversal (a 180º change in phase of an EEG wave between the opposite areas of the brain) cannot be completely discarded (e.g. Hirsch & Brenner, 2010; Niedermayer & Lopes da Silva, 2005).

[4] We thank two anonymous reviewers for bringing this point to our attention.

dition and the two violation conditions, a larger P600 was reported for the phonologically realized than for the phonologically silent conditions. In sum, there are studies in which visually different agreement violations show no different magnitudes of P600 components, while different P600 amplitudes have been also reported in studies in which visually similar agreement violations are compared.

Coming back to our study, if the reported differences were only due to visual saliency, then we would also expect the contrast between the grammatical baseline duzu and the person feature violation **dut* to be larger than that observed between *duzu* and the person+number feature violation **dugu*, because of the larger visual difference between *duzu* and **dut* than between *duzu* and **dugu* (e.g., the latter shares the same length and syllabic structure). However, our data reveal a similar pattern in person and person+number violations suggesting that visual saliency effects are rather small in our experimental design, and thus unlikely to be the main factor responsible for the larger grammaticality effects found for number than for person or number+person feature violation conditions. Hence, although we acknowledge that visual saliency differences between conditions might play a small role in our results, we believe that the main differences between number vs. person and person+number feature violations observed in our results are best interpreted as reflecting a greater prominence of the person phi-feature as compared to the number phi-feature, following the wake of previous ERP studies on verb agreement where visual saliency did not seem to play a significant role either.

In sum, the present data and other cross-linguistic evidence suggest that qualitatively similar but quantitatively distinct ERP effects obtain for person and number phi-features only when the person feature is involved, that is, when either *I* (speaker) and *you* (addressee) are manipulated. Thus, our results are consistent with the claim in linguistics that only *I*, *you* and *we*, forms involving the speaker and the addressee are valued for the person feature (Anagnostopoulou, 2003; Benveniste, 1966; Harley & Ritter, 2002) while third person is the absence of the person feature, a view long held in linguistics (Benveniste, 1966; Jakobson, 1971). This view is convergent with the ERP findings reported across the studies mentioned above: whenever the person feature is involved in agreement computation, a N400–P600 pattern emerges (Zawiszewski & Friederici, 2009; Mancini *et al.*, 2011), while when it is not the LAN–P600 components (Mancini *et al.*, 2011) or the P600 (Nevins *et al.*, 2007; Silva-Pereyra & Carreiras, 2007; Díaz *et al.*, 2011) have been reported. The fact that in the present study person and person+number violations elicited similar responses might suggest that person features do not necessarily combine with number, as argued by Cysouw (2003) and Wechsler (2004).

5. Conclusions

Here, we focused on the core components of verb agreement. We considered the case of subject agreement, and more specifically we investigated whether person and number, the core phi-features, are processed differently. Our results reveal a distinct cost related to person and number feature computation, and clearly signal the saliency of person among the repertoire of phi-features. However, it is well known that agreement patterns can be intricately variable cross-linguistically (Corbett, 1983, 2006, 2009; Baker, 2008; Nevins, 2011, among others), and therefore further research is necessary, across different types of grammars and agreement types, to confirm the validity of these initial findings and to determine how they relate to other aspects of agreement that have yet to be experimentally explored.

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